Predictions of ECS and SSC Emission Models for Flux-Limited Samples of Gamma-Ray Blazars

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The external Compton scattering (ECS) and synchrotron self-Compton (SSC) models make distinct predictions for the amount of Doppler beaming of gamma-rays emitted by blazars. We examine how these differences affect the properties of AGN samples selected on the basis of gamma-ray emission. Using Monte Carlo methods, we create simulated flux-limited samples based on the ECS and SSC models, and compare their properties to those of the Mattox et al. EGRET blazar sample. We find that the two models make very similar predictions for gamma-ray selected samples, and would be very difficult to distinguish observationally by this means. This is primarily due to the fact that not only the Doppler factor, but also the cosmological distance and intrinsic luminosity also play important roles in determining whether a source is included in a flux-limited gamma-ray sample. Our simulations predict that the identified EGRET blazars are highly beamed objects, with a median Doppler factor of $\sim 22 - 35$ and viewing angles $\lesssim 5$ degrees.

Introduction

- Most current models for AGN gamma-ray emission involve inverse-Compton (IC) scattering of "seed" photons off relativistic electrons in the jet.
  - depending on where the seed photons originate, the gamma-ray emission can be Doppler-boosted by different amounts (e.g., Dermer 1995)

- **Synchrotron Self-Compton (SSC) model:**
  - seed photons are synchrotron photons from the jet itself.
  - gamma-ray and radio emission are boosted by the same Doppler factor associated with the bulk jet flow.

- **External Compton-Scattering (ECS) model:**
  - seed photons are external to the jet (i.e., accretion disk, BLR)
  - relativistic speed of the jet causes the spatial distribution of seed photons to appear swept forward in jet rest frame.
  - this enhances the amount of forward IC scattering, effectively increasing the amount of gamma-ray Doppler boosting.
  - **the ECS model suggests that γ-ray-bright blazars should be more highly beamed than the SSC model.**

Goals of This Study

- Traditional technique of testing ECS/SSC model predictions involves difficult multi-wavelength campaigns, the resuts of which have been inconclusive (see Mukherjee et al. 1997)

- Can we use the predicted differences in Doppler boosting instead?
  - what predictions do these two models make for γ-ray-selected samples?
  - how do these compare with the properties of blazars identified by EGRET?

Method

- All 42 robustly-identified EGRET AGNs (Mattox et al. 1997) are bright, flat-spectrum objects with $S_{5\,GHz} > 670$ mJy
  - These would all be members of the Caltech-Jodrell flat-spectrum Sample (CJF), were it not for its declination cutoff ($\delta > 35°$)

- We use the Monte Carlo model of Lister & Marscher (1997) to create a simulated all-sky CJF parent population.
  - we form an EGRET candidate sample by selecting all simulated sources with $S > 670$ mJy from the parent population.

- We assume a simple linear correlation between γ-ray and radio luminosity:
  - $L_{\gamma,SSC} \propto L_{radio}$, and $L_{\gamma,ECS} \propto L_{radio}\ \delta^{1-\alpha}$, where α is the γ-ray spectral index, and δ is the Doppler factor.

- We select the brightest 42 γ-ray sources from the candidate sample, for both the ECS and SSC models.
  - we consider the cases where the γ-rays are created by a continuous jet, or a single emitting blob. (The latter contains an extra Doppler boost due to time dilation).

Results

- The ECS and SSC models make very similar predictions for γ-ray selected samples (Figure 1)
  - Table 1 shows the indicated range of median parameters, derived from multiple Monte Carlo runs.
  - potentially distinguishable parameters are highlighted.
  - **These differences vanish, however, if we add more than ~ 0.5 mag of scatter to the intrinsic radio/γ-ray relation.**

- Compared to typical radio bright, flat-spectrum AGNs, the EGRET blazars are predicted to have:
  - lower intrinsic synchrotron luminosities
  - smaller viewing angles
  - a higher median Lorentz and Doppler factor
  - a higher median superluminal velocity

Discussion

- Similarities in ECS and SSC model predictions are caused by the wide range of intrinsic luminosity and cosmological distance in the parent population.

- In Fig. 1, we plot intrinsic (un-beamed) flux density against Doppler factor.
  - sources lying above the red and blue lines are predicted EGRET blazars according to the ECS and SSC models, respectively.
  - a large number of sources (found in the overlapping region) are predicted by both models.

- Can the situation be improved by using more sensitive γ-ray samples?
  - our simulations suggest that a factor of $\sim 50 - 100$ increase in sensitivity is needed to make statistical distinctions between the ECS and SSC models.

Conclusions

- The ECS and SSC models make similar predictions for the properties of EGRET blazars, despite their different amounts of Doppler boosting.
  - this is due to the additional influence of intrinsic luminosity and cosmological distance on observed flux.
  - more sensitive γ-ray samples may improve this situation.

- Both models predict that EGRET blazars are highly beamed AGNs having only *moderate intrinsic* synchrotron luminosities.

References

Dermer, C. D., 1995, ApJ, 446, L63

Lister, M. L., & Marscher, A. P. 1997, ApJ, 476, 572

Mattox, J. R., et al. 1997, ApJ, 481, 95

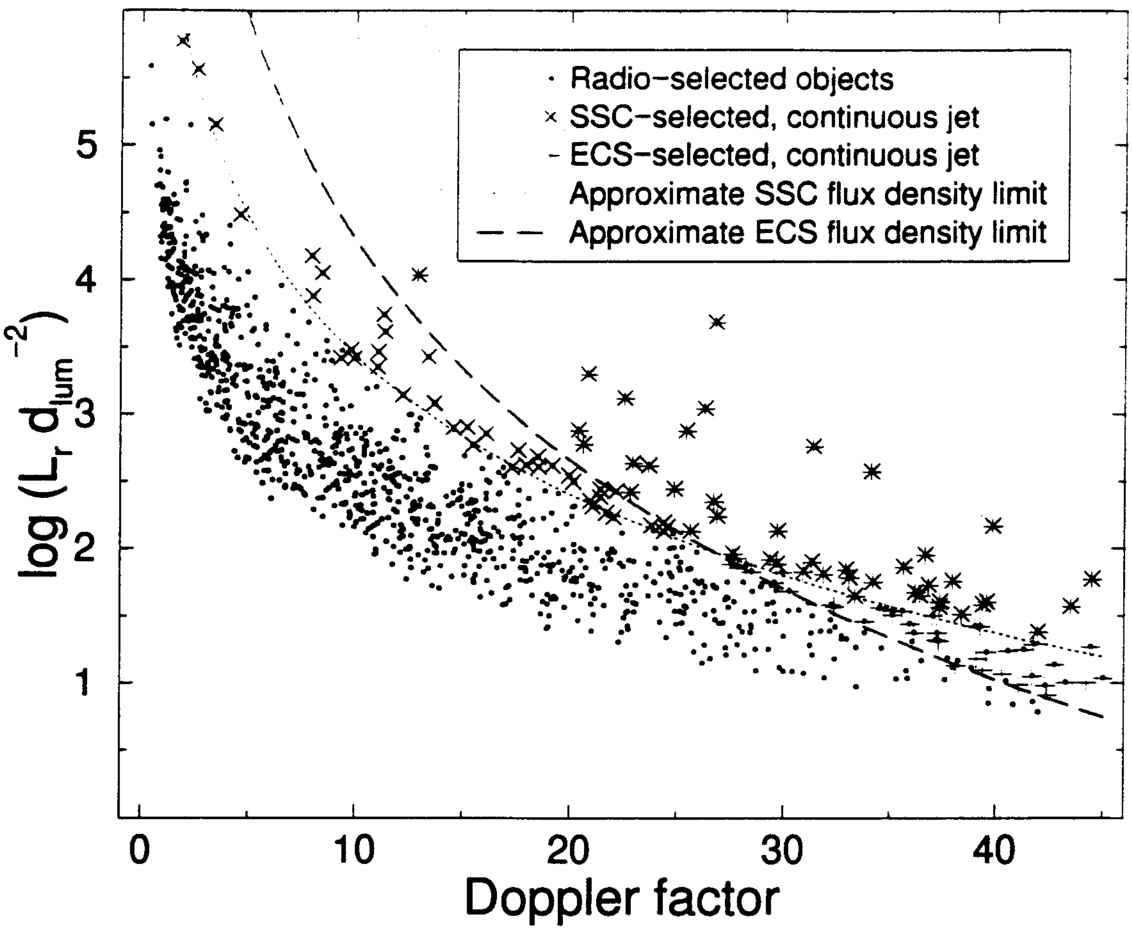
Mukherjee, R., et al. 1997, ApJ, 490, 116

Table 1. Predicted ranges of median parameter values for EGRET blazars

	5 GHz Flux [Jy]	Redshift	log $P_{5\,GHz}$ [W/Hz]	β_{app} h	Lorentz Factor	View. Ang. [deg.]	Doppler Factor
			Continuous jet models				
ECS	**1.5–2.5**	0.6–0.9	27.3–27.8	7–8	19–20	**1.0– 1.3**	**32–34**
SSC	**2.7–4.4**	0.4–0.7	27.1–27.7	6–8	15–18	**1.5–2.3**	**22–26**
			Single blob models				
ECS	1.2–2.1	0.8–1.1	27.3–27.8	7–8	19–20	1.0–1.3	**33–36**
SSC	1.9–3.9	0.5–0.8	27.2–27.7	7–8	18–19	1.1–1.5	**30–32**
			EGRET blazar data				
	2.6	0.9	26.9	...	...	...	...

Fig. 1: Plot of intrinsic (unbeamed) flux density against Doppler factor for a simulated population of flat-spectrum AGNs with $S_{5\,GHz} > 350$ mJy. Sources toward the upper right of this diagram have larger observed (true) flux densities. The blue X's represent those sources with sufficient γ-ray flux to be seen by EGRET, according to the SSC model. The ECS-predicted sample is represented by the red +'s. Note the large number of sources common to both models.

Fig 1.



Radio-selected objects
SSC-selected, continuous jet
ECS-selected, continuous jet
Approximate SSC flux density limit
Approximate ECS flux density limit
log ($L_r\, d_{lum}^{-2}$)
Doppler factor
0
10
20
30
40
1
2
3
4
5